# Summary of the nano-related thermoelectric activities in BGU for the year of 2012

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The search for alternative energy sources is at the forefront of applied research. In this context, thermoelectricity, or the direct conversion of thermal energy into electrical energy, plays an important role, particularly for the exploitation of waste heat. Materials for such applications should exhibit thermoelectric potential and high thermodynamic and mechanical stability.

There is a growing awareness of the relevancy of nanoscience in the context of thermoelectric (TE) power generation. Alloys of type IV-VI, namely PbTe-, GeTe-, and SnTe- based, with $ZT(=\alpha^2\sigma T/\kappa)>1$, where $\alpha$- Seebeck coefficient, and $\sigma$, $\kappa$ are the electrical and thermal conductivities, respectively, are known as the state of the art materials for $T<500^{o}C$ for several decades. Advances over the past decade show that it is possible to enhance *ZT* in nanoscale systems, based on these alloys, by using phonons scattering at interfaces, for reduction of the lattice thermal conductivity, $\kappa_L$. Many of the improvements of the TE performance have been demonstrated in epitaxial, multilayer thin-film geometries or in individual nanostructures (e.g. nanowires). Large scale TE power generation applications involve large temperature gradients and high power densities that can be only obtained in bulk TE materials. It is not surprising therefore that nanostructuring in the latter is currently an active topic of research. Nanostructuring methods in bulk materials, for $\kappa_L$ reduction, include grain size reduction, twin and domain boundaries generation, interfacial nanocoatings, embedded nanoinclusions, lamellar / multilayer structures and others. Recently, our group had obtained and published significantly high *ZT* values of up to 1.8 for nano-structured $Bi_2Te_3$ doped $Pb_{0.18}Ge_{0.87}Te$ [1], putting this composition as one of the best available *p*-type materials worldwide. The *ZT* and thermal conductivity values for this material are shown in Fig.1. The low thermal conductivity for this composition was attributed to nano-sized twinning and dislocation loops (also shown in Fig. 1), resulted from the rhombohedral to cubic phase transition apparent in this material's class.

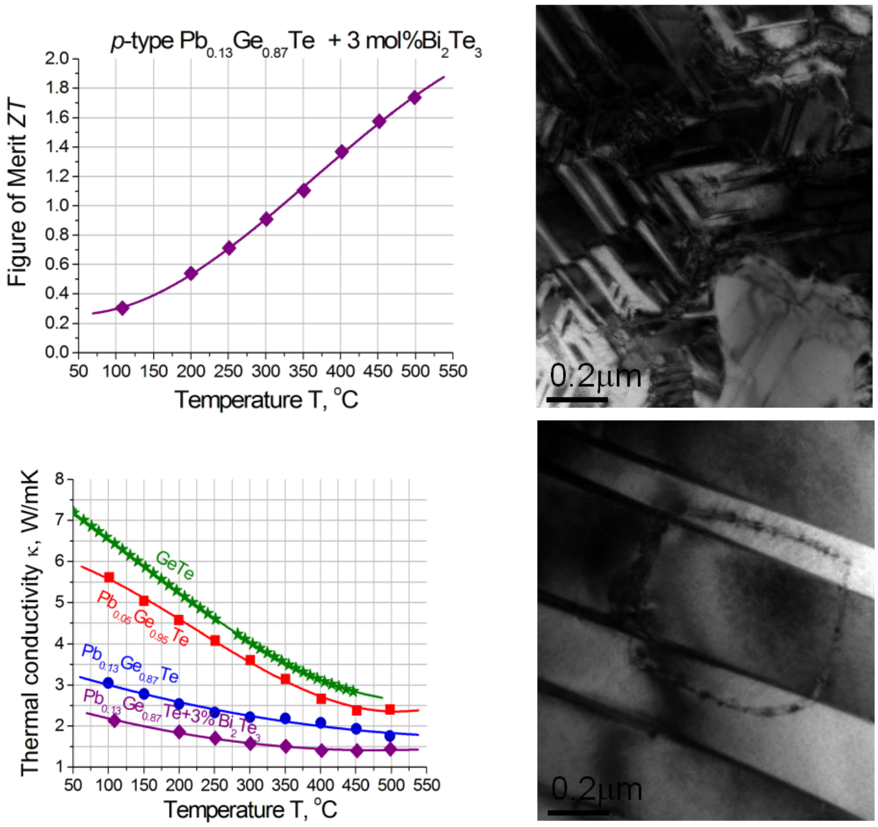


Fig. 1. Dimensilonless figure of merit, *ZT*, thermal conductivity κ and sub-micron twinning and dislocation loop of $Bi_2Te_3$ doped $Pb_{0.13}Ge_{0.87}Te$.

A recently reported thermodynamically driven process that generates a nanostructure in an initially normally structured TE material is based on the spinodal decomposition. Recently, a reduction of the lattice thermal conductivity and a corresponding *ZT* enhancement in $Ge_x(Sn_yPb_{1-y})_{1-x}Te$ systems was attributed by our group (In the frame of a co-supervision with Prof. Moshe Dariel of a M.Sc. student, Yoav Rosenberg, in a second degree research thesis) to nano patterns resulting from the spinodal decomposition [2-5]. An example of an alternating sequence of ~200nm of GeTe and PbTe rich phases, containing submicron twinning and dislocations, respectively, in $Ge_{0.5}Sn_{0.25}Pb_{0.25}Te$, is shown in Fig.2. The maximal *ZT* of this material was found to be1.2, an impressive, beyond the state of the art value for *p*-type materials.

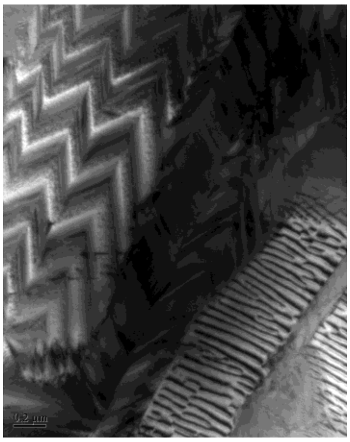

Fig. 2. Alternating sequence of ~200nm of GeTe and PbTe rich phases, containing submicron twinning and dislocations, respectively, for $Ge_{0.5}Sn_{0.25}Pb_{0.25}Te$.


1. Yaniv Gelbstein, Boaz Dado, Ohad Ben-Yehuda, Yatir Sadia, Zinovy Dashevsky and Moshe P. Dariel, "Highly Efficient Ge-rich $Ge_xPb_{1-x}Te$ Thermoelectric Alloys", Journal of Electronic Materials, ***39** (9), 2049 (2010).*
2. Yaniv Gelbstein, Boaz Dado, Ohad Ben-Yehuda, Yatir Sadia, Zinovy Dashevsky and Moshe P. Dariel, "High Thermoelectric Figure of Merit and Nanostructuring in Bulk p-type $Ge_x(Sn_yPb_{1-y})_{1-x}Te$ Alloys Following a Spinodal Decomposition Reaction", Chemistry of Materials 22(3) (2010), 1054-1058.
3. Boaz Dado, Yaniv Gelbstein, Dimitri Mogilansky, Vladimir Ezersky and Moshe P. Dariel**, "**The structural evolution following the spinodal decomposition of the pseudo-ternary $(Pb_{0.3}Sn_{0.1}Ge_{0.6})Te$ compound", Journal of Electronic Materials ***39**(9) 2165-2171 (2010).*
4. Yaniv Gelbstein, Yoav Rosenberg, Yatir Sadia and Moshe P. Dariel, "Thermoelectric Properties Evolution of Spark Plasma Sintered $(Ge_{0.6}Pb_{0.3}Sn_{0.1})Te$ Following a Spinodal Decomposition", Journal of Physical Chemistry C 2010, 114, 13126-13131.
5. Y. Rosenberg, S. Moisa, Y. Gelbstein and M.P. Dariel, "Microstructural Aspects of the Temporal Evolutaion of the Aging Process in Thermoelectric (Pb,Sn,Ge)Te Compounds", Metalurgia International 16(4) 10-12 (2011).